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GREEN MANURING

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सत्यमेव जयते

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PREFACE

THIS publication has been written at the instance of the Indian Council of Agricultural Research, to provide reference material for extension workers, with the object of spreading knowledge of the work among tillers of the soil. Efforts have been made to keep it as non-technical as possible in order to popularise it among practical agriculturists, who want to get the most out of their land.

While attempting to meet this purpose if the authors have digressed into scientific details, it is but natural, as the usefulness of this work largely depends on this source.

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INTRODUCTION

INDIAN farmers are now being asked to produce more food. They are required to feed an ever-increasing population in the country. They have also to produce more fibre, etc. so that our factories may be supplied with enough raw material needed for the manufacture of cloth and other products. This can be achieved, no doubt, to some extent by extra manual labour but to a larger extent by taking the aid of science in farming.

We must give the soil all it requires, not only to produce for the time being but to remain rich for ever. We must give it back the plant-food removed by crops. We ought to treat it as a dependable banker both as regards the safety of deposits, in the form of organic matter and fertilizers, and by the assurance of dividends in the form of bumper harvests. We should grow legumes and green manure crops to absorb nitrogen from the air and add organic matter to the soil. In other words, we have to put life into the soil.

The fertility of Indain soils is low. In order to understand the reason why in a country as old as India, where farming is practised for over 40 centuries, the soil still lacks fertility, a consideration of the condition responsible for it is necessary. Under a hot climate, which prevails throughout the years, the organic matter of the Indian soils burns like fuel. Unless it is continuously replenished, the land cannot remain fertile, the necessity of which is evident from the low yields generally obtained from crops.

Let us now examine the possibilities of the use of such manures with regard to their suitability, cheapness, availability and economic return. The major sources of organic and nitrogenous manures are :

(i) Cattle dung and night-soil

(ii) Composts

(iii) Oil cakes

(iv) Green manures

Burns estimates that 66.6 per cent of the dung produced by animals in India does not go back to the land, and is burnt as a favourite fuel. The rest of the dung is so badly stored before use that it loses most of its nutrients. The fate of night-soil is worse still. Contrary to China where night-soil and compost are in great use—a pit is found almost in every field—there is a prejudice against its handling by Indian farmers. In this way the burning of dung and non-use of night-soil to an appreciable extent have conspired to aggravate the fertile deficiency of soil. There is hardly a ton of farmyard manure available for every acre of land under cultivation. This is far short of even the moderate requirement of crops.

A method to make up the loss due to burning of dung, by mixing a small quantity of manure with farm-waste, was introduced sometime ago, but it has so far not achieved the desired success. The difficulties in popularising compost, in spite of its high quality may be the scarcity of raw material, labour and water.

Oil cake is another good source of combined nitrogen though its present use is limited to cash crops only. High price and difficulty in procurement are the main obstacles against its general use in villages. Until the range of production is so increased as to make it available at a cheap rate everywhere, there is not much chance for its great utilization.

Green manuring is, therefore, the only cheapest and the best source of building up soil fertility. This is a very suitable method of supplying organic matter to the soil , though a bit difficult than is commonly supposed.

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The practice of green manuring is as old as the art of manuring crops. Or, how else, should we interpret the inclusion of those crops in rotation that would shed leaves for incroporation into the soil. In the older farming system it was common in India to bury leaves, twigs and loppings from trees and shrubs where such material was available. Dobbs [1915] has reported the use of all kinds of vegetation for manure, when it could not be put to any better purpose, being a familiar practice with tillers of soil in this country from ancient times.

It is only in the recent past that the old practice has been put to critical examination by actual research and experimentation. The first serious test was made in 1882 at Kanpur by the Department of Agriculture, Uttar Pradesh, and was followed at Nagpur and Damraon in 1893 and 1897. The European planters of India were the pioneers in giving a systematic practice to green manuring as far back as 1890 on the coffee estates of southern India. Later on commencing from 1912 and onwards various workers have studied different aspects of green manuring with numerous crops for increasing yields of field crops especially those of rice, wheat and sugarcane.

It is a well-known fact that nitrogen, for which Indian soils have the greatest hunger, is a very expensive plant nutrient. This can be and cheaply obtained by the inclusion of leguminous crops in rotations, ploughing them under. While green manuring is not the only method for increasing soil productivity, it remains the most fundamental one within the easy reach of poor farmers, particularly when the supply of farm manure is limited in India.

PLOUGHING IN OF CROPS

FOR obtaining bigger yields from the soil and maintaining its fertility, it might just be asked as to how the burying of the crops helps the purpose. The reason is, the addition of plant material increases the contents of organic matter in the soil which in turn releases food in available form for the use of subsequent crops. This change is brought about by the microbial population or the teeth of soil, for which organic matter serves as food. In other words organic matter puts life into the soil. Rightly it has been said 'no soil without life, no life without soil'.

The other function of organic matter is to build soil structure and improve its tilth. A heavy soil can be made porous and crumbly by the addition of organic matter, and thus allow both water and air to move freely in it.

Heavy soils containing sufficient organic matter seldom suffer from bad drainage. These soils can be cultivated soon after the rains due to quick absorption of water.

In light soils, organic matter tends to bind the soil particles, giving it a 'loamy' character. In the absence of good structure, soil neither holds moisture nor stimulate all those biological and chemical processes which are jointly responsible for an increase in soil productivity.

Organic matter and nitrogen are inseparably linked in the soil. As every educated farmer knows, leguminous crops or bacteria on their roots extract nitrogen from the air, which according to an estimate is about 70 million pounds for every acre of land. There is, therfore, an additional increase in the nitrogen content of the soil if legumes are turned under.

When decomposition of organic matter takes place under aerobic condition, not only minerals are released, but also the substances which render difficultly available nutrients into soluble form for the use of plants. In fact organic matter acts as a cure-all for many soil ills.

Compared with cold countries the nitrogen and organic matter contents of Indian soils are very low. On an average there is 0.03 to 0.07 per cent nitrogen and 0.6 per cent carbon in Indian soils as against 0.10 to 0.17 per cent nitrogen and 3 per cent organic carbon in European and American soils (Mukerji and Agarwal, 1950).

In cultivated soils the maintenance of favourable organic status through green and other manures is undoubtedly a sound practice. But it should be clearly understood that there is no advantage, or even much possibility to build up and maintain a level of humus which is not consistent with the climate of the region. Under hot climates, due to rapidity of decomposition, a lower level is almost inevitable. Soil organic matter should be treated as a circulating capital, to which additions must be made, but from which dividends must also be taken in the form of high returns from crops. Organic matter is, therefore, a fund which should be utilised for wise use rather than non-use.

PRINCIPAL GREEN MANURE CROPS

BOTH legumes and non-legumes are used as green manure crops in India. When legumes are used in large quantity, the quota of non-legumes is negligible. The main difference between them is that legumes add both nitrogen and organic matter to the soil, whereas non-legumes supply only the organic matter.

A short description of the common green manure crops is given below :

Legumes

(1) Sannhemp (*Crotalaria juncea*) is a crop most commonly used in India for the renovation of soil. It is a summer legume sown with the break of monsoon and has all the good qualities for a green manure crop. It grows very quickly and attains a height of about four to five feet in a few weeks. Even on poor soils, if they are not swampy, sannhemp can be grown splendidly. The plant contains lot of herbage and does not get woody soon. It decomposes quickly provided the moisture in the soil is not lacking. It is the most outstanding green manure crops.

There are also other varieties of *Crotalaria* used to a limited extent in South India.

(2) *Dhaincha* (*Sesbania aculeata*) occupies the second place after sannhemp for the purpose of green manuring. It is also widely used in this country, and an advantage with this crop is that it can be grown under adverse conditions of drought, water-logging, salinity, etc. without much difficulty. There is another variety of this crop which has been successfully used under water-logged conditions, known as *shevri* or *jayanti* (*Sesbania aegyptiaca*).

(3) There are a number of *kharif* pulses belonging to the genus '*Phaseolus*' used as green manure to a limited extent in this country. Of these, *moth* (*Phaseolus aconitifolius*), *urd* (*Phaseolus mungo*) and *mung* (*Phaseolus aureus*) are important. In Madras and Bombay, another species of this genus called *pillipesara* in Madras and *ranmutki* in Gujarat are also popular.

(4) *Guar* (*Cyanopsis teragonoloba*) is also used as a green manure crop in north-west India, where the rainfall is low and the season is generally dry.

(5) Other leguminous plants such as *lobia* or cowpea (*Vinga catiang*), *kulthi* (*Dolichos biflorus*), wild indigo (*Tephrosia purpurea*) and *arhar* (*Cajanus indicus*) are to a certain extent used as green manure crops.

Besides the above *kharif* or summer crops, there are also a few winter or *rabi* crops used for green manuring. Of these *senji* (*Melilotus parviflora*), berseem (*Trifolium alexandrinum*), *methra* (*Trigonella foenum-graecum*), *khesari* (*Lathyrus sativa*), peas (*Pisum sativum*) and lentil (*Lens esculenta*) are worth trying. Some of them have indicated great promise for use.

Non-legumes

The non-leguminous crops supply a large amount of material for bacteria, though not much of nitrogen, which they draw from soil and thus deplete it for the use of subsequent crop. It is, therefore necessary to replenish the stock of nitrogen so depleted by suitable manuring.

To cite a standard non-legume for green manuring may be rather difficult though quite a few have been used for this purpose. *Bhang* (*Cannabis sativa*) has been found somewhat useful in the Punjab while *kodogira* (*Vernonia cineria*) in Madhya Pradesh. *Juar* (*Andropogon sorghum*), maize (*Zea mays*) and sunflower (*Helianthus anuus*) have similarly been tried in Uttar Pradesh.

Plants and shrubs. Many species of plants and shrubs, both legumes and non-legumes, are grown on bunds or wastelands for the purpose of utilising their leaves and foliage as green manure. The loppings of *Emblica officinalis* and *Mangifera indica* are used in coastal areas to improve salinity of soils.

Sivaraman strongly advocates the production of leaves on the spot for green manuring in rice lands. He recommends *Glyricidia maculata*, a leguminous shrub, for this purpose. It has been found very useful in the South, especially in Madras. By growing this shrub on field bunds at a distance of six feet, it was possible within two years to produce nearly 4,000 lb. of leaves per acre. According to this estimate the yield of irrigated paddy can be increased from 10 to 40 per cent in one year if the above quantity of green leaves are puddled into the field just before transplanting paddy.

Glyricidia can grow well in places with a rainfall of about 20 inches. Its seedlings should be raised and about 100 plants transplanted on the bunds of every acre during rains,

Another rapid growing shrub is *Calotropis gigantea*, a common weed found all over India. Though *Calotropis* is a plant of dry area, there was no difficulty in growing it even in humid places. The plant gets easily established and yields every year about 20 to 40 lb. of leaves at the age of 18 months.

REGIONAL DISTRIBUTION OF GREEN MANURE CROPS

THE details of green manure crops grown in different States of India are given below :

South India

In Madras, black gram, green gram, horse gram, *dhaincha, pillipesara*, sannhemp and indigo are used accroding to their suitability for the different tracts.

Of these, *pillipesara* and *dhaincha* are the two most outstanding crops used for green manuring. Sannhemp is also very much liked, but due to the non-availability of seed it has not been taken up on large scale.

In Mysore, velvet bean has been found suitable both as regards its quick growth and easy decomposition.

In Travancore, where rainfall is heavy, use is made of scrub and loppings for green manuring porpose. In area where conditions permit, sannhemp and cowpeas are grown.

Madhya Pradesh

The common green manure crops among legumes, are sannhemp, *dhaincha* and *terota* (*Cassia tora*). *Kodogira*, a non-legume belonging to composite family is also in common use.

Bombay

Kulthi and niger are used for sugarcane, paddy and maize, while *dhaincha, sheori* and wild indigo are best suited for swampy rice areas. Sannhemp has been found very suitable for sugarcance. Under dry and irrigated conditions *ran-mutki* has also done well.

Punjab

The most common green manure crop is *guar* which flourishes well in areas of low rainfall and poor fertility. The same applies to Rajasthan. *Dhaincha* and sannhemp are also grown to some extent. *Senji*, peas, and berseem are used as winter green manuring crops for cotton.

Uttar Pradesh

The most common green manure crop is sannhemp. The next in order is *dhaincha*. Cowpea is an alternative green manuring crop to sannhemp where land is subject to water-logging. *Mung* is also now becoming popular.

Bihar

As in Uttar Pradesh, sannhemp has been found to be the most suitable crop for green manuring in this State too.

It is preferred over *dhaincha* or cowpea for green manuring wheat, oats and tobacco. For paddy the green manuring is done either with *dhaincha* or sannhemp.

Orissa

Dhaincha appears to be a suitable green manure crop for this State. Work is in progress to find out the best crop for the purpose. Cowpea and other pulses of *Phaseolus* sp. are tried.

West Bengal

The crops that can be grown usefully are *dhaincha*, sannhemp and cowpea according to the local conditions.

Assam

Dhaincha and cowpea are used for acid soils, while sannhemp for normal soils. Green manuring for sugarcane is generally done with cowpea.

NITROGEN ADDITION BY LEGUMES

THE quantity of nitrogen added to the soil by legumes depends on many factors, viz. the kind of legume, the condition of growth, the stage of ploughing in and so forth. It is rather difficult to draw an estimate. The amount of nitrogen in a leguminous plant, however, is the sum total of nitrogen it has taken from both the soil and air. But the amount taken from the air is the one that should count. To assess separately the amount derived from each of these sources is difficult, but in a general term it may be said that about two-thirds of the nitrogen in a legume is derived from air and the rest from the soil.

To give an account of the quantity of nitrogen added by different legumes into the soil is rather difficult. The information regarding a few common plants is, however, given in Table I.

TABLE I

Amount of nitrogen turned under by some of the green manuring crops

Serial number	Common name	Vernacular name	Average yield of green matter md./acre	Moisture per cent	Nitrogen per cent	Amount of nitrogen in lb. turned under per acre	Remarks
			Kharif				Information on the composition of green manure plants is derived mostly from Mukerji (1950) Aiyer (1949) and Pusa report.
1	Sannhemp	*Sanai*	212.2	75	0.43	75.00	
2	*Sesbania aculeata*	*Dhaincha*	200.0	78.2	0.42	68.9	
3	Pulses (*Phaseolus* spp.)	*Urid,*	120	83.0	0.41	38.3	
		Pillipesara	183	75	1.10	49.7	
		Mung	80	75.0	0.53	34.5	

Continued on next page

TABLE I—(*contd.*)

Amount of nitrogen turned under by some of the green manuring crops

Serial number	Common name	Vernacular name	Average yield of green matter md./acre	Moisture per cent	Nitrogen per cent	Amount of nitrogen in lb. turned under per acre	Remarks
4	Cluster beans	*Guar*	200	75		55.7	
5	Cowpea	*Lobia*	150	86.4	0.49	50.3	
6	Horse gram	*Kulthi*	100	71.5	0.33	27.1	
7	Indigo	*Neel*	100	44.7	0.78	64	
			Rabi				
8	Lentil	*Masur*	56	65	0.7	32.8	
9	Peas	*Matar*	201	83	0.36	59.4	
10	*Melilotus* spp.	*Senji*	286	80	0 51	120.1	
11	Egyptian clover	Berseem	155	87	0.43	54.2	
12	*Trigonella foenum-graecum*	*Methra*	116	82	0.33	32.2	
13	*Lathyrus* spp.	*Khesari*	123	79	0·54	54.9	

GREEN MANURING AND SUBSEQUENT CROPS

EXPERIMENTAL work to study the effect of green manuring on the yield of the following food or cash crops has been done in many States in India. A summary of the results of the experiments on different crops is given below.

PADDY

Bombay. *Rui* leaves when green manured at the rate of 8,000 lb. per acre gave an increase of 45 per cent over 'no manure' treatment.

Bihar. Green manuring with *dhaincha* or sannhemp gave 20 per cent increase in yield over 'no manure'.

Madhya Pradesh. An increase of 69 per cent over 'no manure' was obtained with sannhemp as a green manure crop.

Madras. With the addition of green leaves to the soil an increase upto 26 per cent over 'no manure' was obtained.

By turning under of green crops on the basis of 60 lb. nitrogen per acre, an increase upto 100 per cent was obtained over 'no manure'.

West Bengal. Green manuring with sannhemp, cowpea, and *dhaincha* gave 13.5, 16.3 and 14.0 per cent increase respectively over 'no manure.'

Uttar Pradesh. Trials on *dhaincha*, sannhemp, cowpea, etc. over four seasons have shown that 57 to 80 per cent increased yields can be obtained. These increases go even higher, 85 to 90 per cent, with higher seed rates used for the green manure.

Orissa. Green manuring with *dhaincha* resulted in an increase upto 24 per cent.

Wheat

Punjab. An increase of 35 per cent over 'no manure' was obtained by green manuring with *bhang* (*Cannabis sativa*) on sandy loam soils.

Uttar Pradesh. Green manuring with cowpea gave an increase of 20.1 per cent over 'no manure.'

The yield was increased upto 45.2 per cent by turning under of a green sannhemp crop.

Dhaincha was responsible for increasing the yield upto 16 per cent over 'no manure' plots.

Bihar. An increase of 106 per cent over 'no manure' was obtained with sannhemp as a green manure crop.

Madhya Pradesh. The green sannhemp crop when ploughed down gave an increase of 13 per cent over 'no manure' treatment.

Sugarcane

Uttar Pradesh. An increase of 18 per cent over 'no manure' was obtained by green manuring with sannhemp.

At Shahjehanpur (U. P.) an average increase of 43.4 per cent in yield by green manuring with sannhemp was obtained over control.

Madras. Green manuring for sugarcane compares favourably with organic and inorganic manures on equivalent nitrogen basis.

Assam. Green manuring with sannhemp, *dhaincha* and cowpea produced 9.18, 8.40 and 1.77 per cent increased yield respectively over control.

Cotton

Bombay. Green manuring with *dhaincha* gave 12 per cent increase in yield over 'no manure' on deep black soils.

Madras. There was an increase of 19 per cent over 'no manure' with sannhemp as a green manure crop.

Pulses

Bihar. Green manuring with sannhemp for the pea crop gave increase of 23.5 per cent over 'no manure'.

Again, green manuring of sannhemp for *arhar* gave an increase of 6.8 per cent over 'no manure'.

West Bengal. When sannhemp was green manured for cowpea, an increase of 6.21 per cent over 'no manure' was obtained.

ARTIFICIALS IN CONJUNCTION WITH GREEN MANURES

An object most desired in green manuring is to have maximum bulk of green succulence in the shortest possible time. To achieve this, naturally, the soil should be in good heart. On very poor soils, it takes not only a very long time for crops to grow, but also the yields become low. Nitrogen is generally not added to legumes as they take it from atmosphere, though it helps to add a little for ease of decomposition and making nitrates available in time for the subsequent crops.

Phosphates, and occasionally potassic fertilizers, are applied to get high yields from green manure crops. They provide stimulation to the soil micro-organisms. The other advantage of this procedure is to allow phosphates enter into such organic combinations with green matter which may render it easily available to the following crops. In this connection the results of Pusa permanent manurial trials are very interesting. In these trials organic manures, mineral fertilizers, and green manures are compared with each other and also with 'no manure' treatment, under fix rotations. The results obtained from different treatments during a period of 17 years are given in Table II (Parr and Sen, 1948).

TABLE II

Total yield of crops in maunds per acre

Serial number	Treatments per acre per year	*'A' series*	*'B' series*	No. of crops raised during the period
1	No manure	266.4	232.2	34
2	Farmyard manure @ 20 lb. N	369.6	351.9	34

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TABLE II—(*contd.*)

Total yield of crops in maunds per acre

Serial number	Treatment per acre per year	'A' *series*	'B' *series*	No. of crops raised during the period
3	Rape cake @ 20 lb. N	334.2	286.1	34
4	Ammonium sulphate, super phosphate and potassium sulphate (NPK) as in farm yard manure	401.9	338 9	34
5	Green manure and legume in rotation	214.2 (25)	222.7	26
6	Green manure and phosphate (P_2O_5) as in farmyard manure	358.5 (25)	363.7	26

The soil under this experiment is sandy loam with lot of lime in it. In calcareous soils, the phosphoric acid is mostly combined with calcium ; the organic matter being easily oxidized, the phosphorus does not accummulate in organic combinations. Hence, as is evident from the yields of above treatments, the mobilizing agent of phosphoric acid in calcareous soils is organic matter.

A summary of the results obtained in different parts of India with different crops is given below.

PADDY

Bihar. Green manure plus superphosphate at 224 lb. per acre gave 96 per cent increase in yield over 'no manure', while it was only 18 per cent when green manuring was done alone.

Bombay. *Karanj* leaves plus bonemeal at 46 lb. per acre gave an increase of 38 per cent over 'no manure'.

Madras. Green manure plus superphosphate at 50 lb. P_2O_5 per acre gave an increase of 25.7 per cent over 'no manure' while it was only 2.9 per cent in the case of green manure alone.

In another experiment an increase of 66 per cent was obtained over 'no manure'. While in the case of green manuring alone the increase was 34.9 per cent.

Orissa. An increase of 37.8 per cent, when green manuring was done in conjunction with P_2O_5 at 32 lb. per acre was obtained over 'no manure'. While in the case of green manuring alone the increase was 34.9 per cent.

WHEAT

Bihar. An increase of 42.7 per cent was observed when green manuring along with 40 pounds P_2O_5 was done.

Madhya Pradesh. Green manuring with sannhemp plus superphosphate @ 164 lb. per acre gave 20 per cent increase over 'no manure'.

Uttar Pradesh. Green manuring (sannhemp) plus 45 lb. P_2O_5 per acre gave 53 per cent increased yield over 'no manure'.

Delhi (1956). Khan obtained an increased yield of 4.82 md. of *gram* per acre by applying 80 lb. P_2O_5 at the time of sowing sannhemp for green manuring.

COTTON

Bombay. Green manuring *dhaincha* plus ammonium sulphate at 20 lb. nitrogen per acre gave 34 per cent increase over 'no manure'. With green manuring alone, however, there was an increase of over 12 per cent.

Uttar Pradesh. Green manuring sannhemp plus super @ 18 lb. P_2O_5 per acre gave an increase of 17.6 per cent over 'no manure'.

Bihar. Green manuring plus superphosphate at 80 lb. P_2O_5 per acre gave 246 per cent increase in yield of pea at Pusa over 'no manure' while it was only 23.5 per cent with green manuring alone.

West Bengal. Green manuring plus bonemeal at 250 pounds per acre increased the yield of cowpea by 390 per cent compared to green manuring alone where an increase of 104 per cent was noted.

Delhi. The different stages of burying sannhemp in conjunction with artificials were studied in relation to their effect on the yield of wheat by Khan and co-workers. The unpublished results are given in Table III.

TABLE III

Yield of wheat in maunds per acre

Treatments per cent	Superphosphate @ 80 lb. P_2O_5 (1)	Ammonium sulphate @ 15 lb.N/acre to gm. (2)	Super and ammonium sulphate as in 1&2	Control	Average
Sannhemp buried after 4 weeks of sowing	20.67	19.58	18.49	16.9	18.91
,, ,, 6 ,, ,,	17.39	17.51	18.24	16.54	17.42
,, ,, 8 ,, ,,	25.42	21.16	23.84	23.11	23.38
,, ,, 10 ,, ,,	20.07	16.30	18.49	15.57	17.63
Average	20.89	18.67	19.76	18.03	

Differences are statistically significant

The same workers in an earlier experiment on green manuring in conjunction with fertilizers obtained the yields as shown in Table IV.

TABLE IV

Yield of wheat (C. 518) in maunds per acre (1948-49)

Treatments	Control (1)	Ammonium sulphate a 40 lb. N per acre at the sowing of wheat (2)	Superphosphate@ 80 lb. P_2O_5/acre at the time of burying green manure (3)	N and P as in 2 and 3 (4)	Average
No manure	11.64	15.77	11.32	21 79	15.10
Sannhemp grown *in situ* and buried	18.92	18.80	20.21	25.24	20.79
Sannhemp brought from outside at 200 md. (green weight) per acre and buried	13.18	17.30	10.70	24.79	16.52
Sannhemp composed and buried at 200 md. (green weight) per acre	13.95	13.92	17.14	25.46	17.62
Average	14.43	16.48	14.82	22 24	

Differences are statistically significant

RESIDUAL EFFECT OF GREEN MANURES

THERE is a loss of one season when *kharif* legumes like sannhemp, *dhaincha* or *guar* are ploughed in. The yield obtained from the subsequent crop may or may not be high enough as to cover this loss. It is, therefore, important to take into account the yields obtained from all crops in rotation rather than the one following. Experimental results have shown that green manure has a marked effect on the yields of all subsequent crops due to residual carry over.

Hutchinson [1923] observed a marked residual effect of superphosphate in conjunction with green manure than superphosphate or green manure alone.

In Kashmir, Fotedar [1946] observed the residual effect of green manure with lentil lasting for three years.

At the Indian Agricultural Research Institute, Delhi, Khan and co-workers studied the residual effect of sannhemp as a green manure crops on maize and wheat in a green manure-wheat-maize wheat rotation.

TABLE V

The results of two cycles (unpublished)
(yield in maunds per acre)

Treatments	Maize grain	Wheat grain	Maize grain	Wheat grain
No manure	4.55	5.33	Crop failed due to heavy rains and water-logging	8.41
Sannhemp grown *in situ* and buried	7.92	7.50		11.11
Sannhemp brought from outside at 200 maunds green per acre	5.96	6.19		9.31
Sannhemp composted and buried at 200 maunds green per acre	5.03	5.86		11.29

It is evident from the results that green manure p ots have invariably given higher yields than the controls. If calculated on the basis of the standard practice of green manuring 'at site', the difference in yield between the control and green manuring treatment is a substantial one in favour of the latter, making the practice economically sound.

EXTENT OF GREEN MANURING

GREEN manuring is done to add a great bulk of organic matter in the soil and thus enrich it with nitrogen, a major plant food which is chiefly deficient in our soils. More than 90 per cent of the nitrogen in soils is usually present as a constituent of organic matter which becomes gradually available to the plants as decomposition proceeds. So long as nitrogen exists as a part of the organic matter, it is neither subject to leaching nor available to plants. Soon after the organic matter decomposes, nitrogen is gradually released first as ammonia which may be directly absorbed by plants or oxidised to nitrates, which may be rapidly leached if not used. Organic matter is not only a principal source of nitrogen, but also of phosphorus, calcium, sulphur, and other mineral constituents of plants including the minor elements, which are only minor in quantity but not in function.

It would thus appear that it is very necessary to keep the organic status of Indian soils high. Unfortunately, in a hot climate like that in our country, it is not possible to build up a high reserve of organic matter. The only way to keep the reserve is by striking a balance between production and depletion. This will depend on many factors, e. g. the climate, soil type, cropping system, economic independence of the farmer and many other related facts.

Though considerable work has been done on green manuring in India, the information on the above point is rather meagre. In this connection a trial was conducted for a period of seven years at the Indian Agricultural Research Institute farm at Delhi. The results (unpublished) can be seen in Table VI.

TABLE VI

Yield in maunds from small holdings of eight acres each

(experiment spread over seven years)

Particulars of produce	Holding without green manuring			Green manuring once in two year (50 per cent intensity)			Green manuring twice in three years (66 per cent intensity)		
	Total area in acres	Total yield	Average yield per acre	Total area	Total yield	Average yield per acre	Total area	Total yield	Yield per acre
Pulses	21.00	278.17	13.25	19.00	255.35	13.44	12.00	197.89	16.49
Cereals	37.25	704.41	18.91	35.50	886.93	24.96	38.50	1042.34	27.07
Green fodder	31.50	7328.22	252.64	16,00	4709.38	294.34	1.25	3594.51	293.43
Bhusa and maize stalk	56.25	1429.66	25.42	53.00	1666.60	31.45	49.75	1800.65	36.21
Cotton	2.00	14.10	7.05	5.00	46.63	9.33	2.50	27.52	11.01

An examination of the data in this table clearly indicates the superiority of 50 per cent inensity of green manuring, (i.e. once in two years) over the others. There is a substantial increase in the yields of crops in green manured holdings over the ones without green manuring. From monetary point of view it is evident that the practice of green manuring is economically sound.

TECHNIQUE OF GREEN MANURING

IN order to draw maximum benefit from green manuring one should have a clear understanding of the cultural practices to be followed in the process. On these depend, generally, the success or failure of the system. The sowing of green manure crop may be so arranged as to facilitate its burial at the stage when it would furnish the maximum amount of plant food to the soil. The 'time' interval between burying and sowing of next crop needs correct adjustment in a manner that the nutrition provided by the green crop may not be lost. Also, the soil conditions for easy decompositions of organic matter have to be looked into.

Time of sowing : There can be no general recommendation for a vast country like India where climate differs from region to region. The concensus of opinion, however, is that it should be sown as early as possible after the break of monsoon In Bihar, it may be early June, while in other States of northern India a little later. Under irrigated conditions in Madras, Ramiah, recommends the sowing of green manure crop for paddy in, as early as, the middle of March. For Uttar Pradesh, Sethi is of opinion that it may be sown in the beginning of June, if irrigation is available or, otherwise, after the arrival of monsoon. The best time for green manuring in the case of sann, *urid* and *dhaincha* in Bombay has been suggested as June or early July. The advantage in establising the crop earlier than the setting of monsoon is to resist the damage from heavy rains afterwards.

Time of burial : Coleman [1912] in Mysore suggests flowering stage as the best stage for turning under a green crop.

Hutchinson [1914] and Milligon think that 4 to 6 weeks older plants are better than the 10 weeks old ones.

Allan [1915] is of opinion that in a short monsoon season the material must be turned in by the first week of August.

Joshi [1922] is in favour of burying plants at maturity.

Singh and Singh [1936] found bud stage, i.e. 75 day after germination, to be the best time for manuring.

Sethi, *et al.* [1938] found the 50 days old crop of sannhemp best for nitrogen accumulation.

Rege [1941] recommends initial flowering state as the best stage for inversion in Deccan,

Mitra and Gupta [1942] found seven weeks old crop of sannhemp best for burying for paddy in Uttar Pradesh.

Khan and co-workers [1951] found eighth week as the best time for turning under of sannhemp in Delhi.

A general conclusion which may be drawn from the above work in different parts of the country is that a green crop may be turned under at a stage when it is just about to flower. This may roughly coincide with a period of eight weeks from sowing in the case of most of the crops.

Decomposition of green matter : This is carried out in the soil by a number of different agencies responsible to effect complete disintegration of various tissues, leading upto ammonification, and final nitrate produ-tion. The requirements for complete decomposition are varying moisture and air condition in the soil. The desired results would follow if moisture contents are high in the beginning leading to semi-anaerobic fermentation of resistant material, and low afterwards for inducing aerobic condition under which nitrification takes place. It is, therefore, obvious that failure of rains during early stages of decay would largely account for loss of manurial effect on the succeeding crops. Contrarily, late and heavy rains will tend to destroy the favourable action of nitrates already formed. Hence the rapidity of decomposition, among other factors, depends on moisture content of the soil, composition of green matter and presence of available inorganic nutrients.

The depth of ploughing in of green matter and especially its proper incorporation in the soil by means of some iron inverting plough is also important for quick decomposition. In light soils, the crop, as a rule, be buried deeper than the heavy ones.

Opinions differ in regard to the raising of green manure crops at site or elsewhere for the purpose of burial. Experiments conducted at Delhi and Bombay are in favour of growing at site, though it becomes difficult for the paddy crop if the land is water-logged. The advantage of growing crop outside is the transfer of moisture and soil nutrients of one field to the other.

'Time' interval between burial and sowing of next crop. The time lag plays a very important part in the decomposition of organic matter, and in making nitrates, formed during the process, available to the following crops at the opportune time.

It has been observed that under Pusa (Bihar) conditions, the period of maximum notification was at the end of eight week. Joshi [1919] holds the view that the rate of nitrification is in inverse ratio to the succulence of the stem.

Howard, Allan, Hutchinson and Milligan are in favour of two months' interval for sann green manuring to give the best results.

Green manuring, in short, is a practice of 'timings'. It succeeds only when the time of burying the green crop fits in with the time of sowing the next crop. The experience of the 'interval' required for the green crop to decompose and produce nitrate is essential. Once it is known, the sowing of the subsequent crop can be arranged in a way that nitrates may not be lost due to leaching or reduction. Those farmers who have the knowledge of correct timings are successful ; others are not. If this is rightly done, green manuring not only becomes a sound practice but also a valuable aid in farming.

RELATIVE VALUES OF GREEN AND OTHER MANURES

THERE is not much work done in India on this aspect of the problem. Since cattle dung is still the main source of organic matter added to the soil, it would be worthwhile to compare its efficiency along with other manures, with green manuring. A summary of work done in India is presented below.

In Bihar, it has been reported that green manure is better than farmyard manure. In the case of sugarcane, however, when phosphate was also applied the latter was found superior, though juice was richer in the case of the former.

In Bombay, no statistical significance was noted between farmyard and green manure on the yield of cane, though farmyard manure in both the years of trial gave lower yields than green manure.

In Uttar Pradesh, no differnce was noted in yields of cane and wheat obtained by different applicatians of farmyard, compost and green manures.

In the black cotton soils of Surat tract (Bombay State) where green manuring was compared with farmyard manure on cotton and *jowar*, the beneficial effect of green manuring was clearly indicated.

Work was done at the Indian Agricultural Research Institute farm in Delhi on the value of nitrogen in organic and inorganic manures for a period of six years. The results are given in Table VII.

TABLE VII

*Yield of wheat in maunds per acre**

Treatment		1944-45	1945-46	1946-47	1947-48	1948-49	1949-50
Green manuring with sannhemp		28.12	20.72	13.88	15.37	24.30	25.42
,, ,, cowpea		31.19	20.23	15.53	16.39	22.73	20.21
Mustard cake	40 lb. N/acre	33.03	22.43	16.44	15.73	27.73	17.41
Castor cake	,, ,,	32.29	20.54	16.31	18.08	20.18	15.99
Farmyard manure	,, ,,	33.43	19.96	14.48	17.65	18.67	14.20
Compost	,, ,,	29.08	20.45	18.98	16.35	33.12	14.47
Ammonium sulphate	,,	26.73	22.21	17.67	9.62	23.17	17.41
Control		27.25	19.33	17.62	12.38	20.94	13.93

*Data unpublished

From the results of work done so far it may be indicated that green manuring is superior to farmyard manure and compares favourably with other forms of manures and fertilizer.

ECONOMICS OF GREEN MANURING

WHETHER the increased production through green manuring pays for the loss of one crop season, is the main point on which the farmers are to be satisfied. They are not going to adopt any method, however scientific it may be, unless it is based on sound economics. The subject needs a thorough study for a long period wherein the residual effect has been accounted for.

Roberts [1913] recommends the practice of green manuring, as paying in the Punjab, on poor lands only.

Rege [1935] is of the opinion that the actual replacement of paying crop by green manure crop can hardly be economical unless the green manure is specifically meant for sugarcane.

Lander [1937] thinks that the practice of green manuring is paying in the Punjab if the residual effect is also taken into account.

Gadgil [1937] calculates the cost of green manuring with sann in the Deccan canal area including the cost of cultivation, seed, rent, etc. to be Rs. 43/- per acre, or 6 as. 9 ps. per pound of nitrogen to which if the cost of alternate *kharif* fodder be added the total amount would become Rs. 65/- or 10 as. 4 ps. per N lb. Even this is economical if compared with the cost per pound of nitrogen in farmyard manure.

Green manuring has been found profitable for paddy in Bombay and Uttar Pradesh. Similarly for sugarcane it was found economical in Uttar Pradesh.

To study the economics of green manuring at Delhi (Indian Agricultural Research Institute farm), an experiment was started by

Chandnani and associates during the year 1950-51. The results are given in Table VIII.

TABLE VIII

Results of experiments to study economics of green manuring

Treatment: *Kharif*	Treatment: *Rabi*	Value of total produce (grain and *bhusa*) Rs.	Total expenditure Rs.	Net profit Rs.
	Fallow	144.6	96.0	48.6
Fallow	Wheat	297.7	133.4	164.3
Maize	Wheat	354.2	199.8	154.4
Maize with 10 tons of F. Y. M.	Wheat	454.2	285.2	169 0
Maize	Peas	265.9	135.4	130.5
Sannhemp green manuring +60 lb. P_2O_5 per acre	Wheat	418.0	204.0	214.0
Groundnut with 60 lb. P_2O_5 per acre	Wheat	357.2	272.0	85.20
Sannhemp grown in alternate rows with maize +60 lb. P_2O_5 per acre	Wheat	429.6	247.0	182.6

From the above it is evident that considering the outlay and cash returns the best profits were secured through green manuring. Double cropping or leaving the land fallow in one season did not show better returns than green manuring which justifies the soundness of the practice.

GREEN MANURING ROTATIONS

THE use of green manures in this country is mostly confined to important food and cash crops. Some such crops with which green manuring is practised are paddy, wheat, sugarcane and cotton. It may not be out of place here to point out that mere inclusion of a green manure crop does not eliminate the use of legumes in rotations. Their contribution to augment the yield of crops is definite. This view is being supported by the results of Pusa permanent manurial experiments, where green manuring alone for cereals did not give as high yield as was secured by including a legume in rotation. A discussion of rotations with different crops follows :

Paddy

Ramiah [1935] observes if a green manure crop is grown between rice and sugarcane in a two year rotation, the yield of rice could be maintained at a high level inspite of the fact that sugarcane is an exhaustive crop.

At Karnal (Punjab) the yield of rice was always high in a paddy berseem rotation, especially when the last cutting of berseem crop was turned in.

Under irrigated condition for a transplanted paddy the practice in Uttar Pradesh is to sow green manure crop *in situ* in May for burying in the beginning of July. The yields obtained are reported to be high.

Wheat

The common rotations with wheat are :

(i)	Green manure wheat- cotton-green manure-sugarcane	U. P. and Punjab
(ii)	Green manure-wheat- maize-*arhar*	Bihar

(iii)	Green manure-wheat groundnut-sugarcane	Bombay and U. P.
(iv)	Green manure-wheat-maize-peas	U. P. and Punjab
(v)	*Jowar* fodder-gram-green manure wheat	Rain-fed tract with a rainfall of 25 inches or above

The above noted are some of the successful rotations with wheat followed in different parts of India.

Sugarcane

Sayer [1935] observed in Bihar that the yield of cane is considerably increased if three green pulses instead of two intervene in a four-year rotation.

According to Mukerji [1950] green manuring is done once in three years with cane in Bihar.

The usual rotation followed with cane in Uttar Pradesh and Bihar is green-manuring-sugarcane-fallow-wheat

In a tract where cotton precedes sugarcane it is a good practice to have an undersown crop of *senji* or berseem for turning under. In this way the yield of cane is considerably increased.

Cotton

The common rotation with cotton are given below :

Wheat - *toria* (green manure) - cotton Maize - *senji* (green manure) - cotton	Punjab
Sugarcane - green manure - wheat-cotton	U. P.
Jowar - groundnut - cotton *Bajra* - *arhar* or groundnut - cotton	M. P.

Cotton - *jowar* - groundnut	}	Bombay
Cotton - *bajra* - groundnut		
Sugarcane - cotton - *nilwa* - gram	]	Madras

It will be evident from the above mentioned rotations that green manuring direct to cotton is not in practice. On the other hand, green manuring is done to some other food or cash crops in the rotation and advantage of residual fertility is taken on it. In Bundelkhand, Uttar Pradesh, [1934] the residual effect was quite appreciable on cotton sown after green manuring wheat.

At Aligarh [1934] in Uttar Pradesh the green manuring of wheat considerably increased the yield of the succeeding crop of cotton.

But it does not mean that direct green manuring of cotton in a rotation would not pay. In Madras, green manuring of cotton with sannhemp gave significant increase over no manure.

In Bombay, 230.1 per cent increase was obtained over control by growing cotton after green manuring. *Jowar* which follows cotton also gave an increase of 146.8 per cent over control.

Green manuring can be practised safely under a well-distributed rainfall of about 25 inches or with irrigation.

SUMMARY

THE possibilities of green manuring and its limitations are discussed in this publication, a short summary of which is given below.

Possibilities : The practice of green manuring is an important feature of Indian agriculture. It is common in several States. Due to continuous cropping and burning of the dung which is the main source of organic matter and nitrogen to the soil, the fertility of the land has considerably declined. Green manuring is by far the best and cheapest method of meeting these two important requirements of our soils.

Various species of leguminous plants both summer and winter have been tested as green manure crops. Of these a few most commonly used are : Sannhemp, *dhaincha*, *pillepesara*, *guar* and cowpea. There is hardly any non-leguminous plant worth the name which has been generally adopted for green manuring purpose. The choice of a green manure crop is mainly local. Sannhemp is, undoubtedly, the most universal crop for green manuring.

Under favourable circumstances, green manuring can cause great increase in the crops that follow it. There is wide experience and experimental data to support this statement. Some of the crops with which green manuring has been adopted as practice are, transplanted paddy, sugarcane and irrigated wheat.

In Madras, Madhya Pradesh, Uttar Pradesh, Orissa and Bengal, the yield of paddy has been increased through green manuring. Sannhemp, *dhanicha* and cowpea have been reported to be good for this purpose :

Green manuring was responsible to increase the yield of cane considerably in Uttar Pradesh, Assam and other places.

Wheat has been benefitted by green manuring in places where sufficient moisture was available in soil either due to rains or irrigation.

The response to fertilizers, especially phosphates in conjunction with green manures, has been remarkable. Higher yields of subsequent crops were invariably obtained.

The profitable use of green manuring to build up and maintain soil fertility depends upon the successful production of both the green manure and subsequent crop. This implies that the farmer should have sufficient skill to raise and bury green manure crop in such a way as to be of maximum advantage to the subsequent crop. It can be done only if the time of ploughing in of a green manure crop fits in with the time of sowing the next crop.

Limitations : The practice of green manuring is rendered difficult by climatic, technical and economic causes. Green manure crops need a quick and certain start during the short period of their growth. This can be achieved if the season is favourable. Lack of moisture, both at the time of growth and after burial, is harmful. A dry and undercomposed crop may temporarily decrease the supply of nitrogen to the growing crop and thus become harmful. An adequate supply of moisture can be insured either by a well-distributed rainfall of 25 inches and above, or through irrigation.

The technical difficulties involved in the art of green manuring are largely due to the lack of full knowledge of the correct procedure in regard to the stage of maturity and the best method of burying green crop. The time of burying green manure crop and the sowing of subsequent crop needs be so adjusted as to avoid any possible loss of nutrition provided for the latter.

Non-availability of seed is sometime responsible for restricting the practice of green manuring with a certain promising crop.

The economics of green manuring from the point of view of small cultivator will largely depend upon the possibility of producing green manure crops without disturbance to those main crops which support the finances of the cultivator.

The evidence on record supports the view that green manuring is the best, cheapest and a sound practice.

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